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A GRAZING MODULE FOR ARC HABITAT SUITABILITY INDEX SOFTWARE

by

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INTRODUCTION

Timber harvest and grazing are tools the U.S. Forest Service uses to manipulate vegetation while providing economic benefit from natural resources. ArcHSI (Juntti and Rumble 2006) was developed to evaluate land management alternatives of timber harvest strategies on the habitat suitability of a variety of wildlife species. Habitat suitability is defined as the ability of an area to meet the life requisites of a wildlife species. The model associates vegetation structural stages (e.g. Buttery and Gillam 1993) to the habitat requirements of food and cover. For deer and elk habitat suitability also includes the juxtaposition of food and cover, and effects from proximity to roads. (Lyon 1983, Wisdom et al. 1986, Thomas et al. 1988, Rowland et al. 2000) and ArcHSI incorporates these spatially explicit factors into the habitat suitability calculations. The relations between forage, cover, juxtaposition of forage and cover, and proximity to roads in assessing habitat suitability for elk have been researched and revised in the Black Hills through several iterations (Rumble et al. 2001, Benkobi et al. 2004, Rumble et al. 2007).

A large literature base exists documenting interaction between elk and cattle (see Wisdom and Thomas 1996). Theoretical and empirical research has shown that diets of cattle are generally similar to diets of elk, with dietary overlap varying between 40 and 88 percent (Hanley 1982, Kingery et al. 1996, Torstenson et al. 2006). Consequently, the amount of forage remaining after grazing by cattle can directly affect the value of those ranges for elk during winter. Winter is a period when the available herbaceous biomass affects energy balances of elk (Wickstrom et al. 1984) and when foraging elk demonstrated strong selection for vegetation structural stages with greater herbaceous biomass (Rumble et al. 2007). However, the interaction between livestock and elk s has not been incorporated in calculations of habitat suitability for elk. We hypothesized that

habitat suitability and elk distributions would be affected by ed on the estimated amount of forage left after grazing by livestock. Here we report the effects of livestock grazing on the distribution of elk, propose a grazing component for incorporation into the winter ArcHSI elk model, and test the predicted effects on HSI using diurnal elk locations.

STUDY AREA

The Black Hills extend approximately 198 km north to south and 99 km east to west, mostly in South Dakota, but include portions of eastern Wyoming. Elevations range from approximately 915 m in the eastern foothills to 2,207 m in a central granitic core and on the western uplifted plateau. The climate surrounding the Black Hills is continental with low winter and high summer temperatures. Winter temperatures vary with elevations and average from 5° to 6.7° C. January is the coldest month (1.8 to –11° C) while July and August are the warmest months (15 to 29° C). Annual precipitation ranges from 46 cm to 66 cm (Orr 1959) with June as the wettest month. Winter precipitation is greater in the northern and western portions.

Our study included two areas in the west-central and northern Black Hills (Figure 1). The northern study area included that portion of the BHNF north of U.S. Highway 85 in Wyoming and South Dakota and the northern portion of the western uplifted Limestone Plateau. Elevation ranges from 2,100 m in the southern portion to <1,200 m at the northern boundary of the BHNF (Thilenius 1972). The northern half of the north study area contains steep canyons and drainages that feed several perennial streams. The southern study area also included the Limestone Plateau with elevations ranging from approximately 2,100 m in the north to 1,800 m in the south. Precipitation and snow depths decrease with the loss of elevation from approximately 56 cm to <50 cm in both study areas (Orr 1959). Both study areas were dominated by ponderosa pine (*Pinus*

ponderosa). White spruce (*Picea glauca*) and quaking aspen (*Populus tremuloides*) occur in mesic sites and at high elevations on slopes with northerly aspects (Hoffman and Alexander 1987). Road density in the northern area was 2.51 km/km^2, while road density in the southern area was 2.13 km/km^2. These road densities could reduce the effectiveness of habitat by 70% (Lyon 1983).

Late August to early September a wildfire burned approximately 34,413 ha (85,000 ac) that encompassed 65% of the elk winter range from the previous winter. Most of the elk were displaced to the south west or south east of the winter range (Benkobi et al. 2005). With the exception of a trespass cattle from a private ranch, no livestock were permitted during the summer 2001.

METHODS

Stocking rates of livestock on lands managed by the Forest Service are based on animal unit month (AUM) which is the amount of forage consumed by a 1,000 lb cow and a suckling calf ≤300 lbs (Alberta Dept. Agriculture 1987) in 30 days. Cattle consume approximately 2% of their body weight per day (26 lb or 11.8 kg) in dry herbaceous material (National Research Council 1984). We obtained the number of cow/calf pairs and number of days pastures were graze from the annual operating instructions and calculated the amount of forage removed by livestock as: *Consumption = # cow/calf pairs x 11.8 kg/day x # days grazed.*

We estimated standing crop for vegetation structural stages in the west-central to northern Black Hills (Figure 1) from August to September of 1999,2000 and 2001. We clipped, air-dried and weighed grasses and forbs in 4, 1-m^2 circular plots at 511 sites using a stratified random sampling design based on vegetation structural stages. Vegetation structural stages are a hierarchal

classification of vegetation in the Black Hills National Forest based on vegetation type, size class of trees, and overstory canopy cover categories (Buttery and Gillam 1983). We estimated the proportion of residual stand crop for all vegetation structural stages in a pasture after grazing by livestock as: $Residual = 1 - \frac{Consumption}{Standing\ crop}$.

Seasonal use by elk

All of our evaluations were based on diurnal locations of elk. In doing so, and evaluating elk distributions relative to habitat suitability in pastures, we assumed that elk remained within pastures despite crepuscular movements between foraging and cover.

Summer -- Between August 1998 and October 2001, we systematically located approximately 70 (50 females and 20 males) radio-collared elk on a study area in the west-central and northern Black Hills. The actual number varied due to mortality and our ability to capture additional elk and place radio transmitters on them. We made several preliminary evaluations of the interaction between livestock and elk. Using elk locations between June and October 1999 and June to September 2000, we evaluated elk use of pastures elk relative to the stocking rate using a Design I analysis (Manley et al. 2002). We then further evaluated the elk use in heavily grazed pastures by evaluating elk use of these pastures before, during and after livestock grazing also using the Design I analysis.

Winter -- We selected an area that encompassed a the 95% kernel utilization distribution (Hooge et al. 1999) of elk locations obtained from radio telemetry from 1 November 1999 to 29 February 2000 to test effects livestock grazing had on elk distributions. This area was intersected in GIS with the boundaries of range allotments for which we had annual operating instruction (to

calculate stocking rates) for the livestock grazing from the 1999 season from the Black Hills National Forest. We included the entire pasture if any of the pasture was included in the 95% kernel area.

Using the estimates of standing crop for vegetation structural stages and proportion of residual standing crop remaining, we calculated an area weighted estimate of forage density for each pasture based on i vegetation structural stages in a pasture:

$$Forage\ density = \frac{\sum_i Standing\ crop_i \times area_i \times proportion\ residual_i}{1429\ kg/ha \times Pasture\ area}$$. Thus, a pasture that was ungrazed and comprise entirely of grassland would have a forage density of 1.0. Pastures were categorized into 3 approximately equal categories and we evaluated the distribution relative to vegetation density in pastures using the Design I analysis.

We applied the winter ArcHSI model (Juntti and Rumble 2006) to the forest inventory data for the 95% utilization distribution determined from fixed kernel estimates and tested the elk distribution in HSI categories against a random use of pastures using the Design I analysis (Manley et al. 2002). For this application of the model we did not include the effects of roads, because our data on elk was diurnal observations. Elk may move away from road during the day and return to better foraging habitat at night (Millspaugh 1999). Most good foraging areas (meadows) in this area had roads and while elk would avoid these during the day, they could remain within the pasture and select these habitats at night. ArcHSI calculates HSI for elk as a weighted arithmetic average of forage value (FV), cover value (CV), habitat distribution value (HDV) and effects of roads on elk use of habitats (ROAD) using the formula: $\left[\frac{3 \times FV + CV + HDV}{5}\right] \times ROAD$.

Updated coefficients have been proposed for the ArcHSI model (Rumble et al. 2007), but we

elected not to use because they have not yet been adopted by the Black Hills National Forest. We then implemented an adjustment to the HSI for elk by adjusting the forage value (FV) of vegetation structural stages in the ArcHSI model by the proportion of residual forage remaining in pastures after grazing: $\left[FV_{Grazing} = FV_{ArcHSI} \times Residual\right]$. We then substituted the FV adjusted for grazing to calculate HSI for elk as described above. We then tested the null hypothesis that the distribution of elk was similar to the distribution predicted by HSI categories output from the ArcHSI using the Design I (Manley et al. 2002).

RESULTS AND DISCUSSION

Table 1 shows estimated standing crop of grasses and forbs in vegetation structural stages and not vegetative production. Our estimates of standing crop generally agree with previously published reports of vegetative production in the Black Hills of South Dakota (Pase and Hurd 1957; Pase and Thilenius 1968, Uresk and Severson 1989). Our estimates in meadows are about 100 kg/ha less than reported by Pase and Hurd (1957). Soils in our study area include the most productive soil types in the Black Hills (Bennett et al. 1987). Mountain mahogany shrublands were on shallow soils with little herbaceous vegetation which accounts for the atypically low herbaceous vegetation in shrublands.

Because of the Jasper fire in September 2000, we did not have accurate annual operating plans for major portions of our study area. Consequently, we emphasized our analyses on the 1999 grazing season. During the 1999 grazing season, elk were not distributed proportionally among pastures ($\chi^2 = 29$, $P < 0.01$) and appeared to select pastures stocked at >7.5 cow-calf pair days/ha (3.03 cow-calf pair days/ac) and avoided pastures stocked at less than 7.5 cow-calf pair days/ha (Table 2). All of the selection ratios differed from proportional availability or a selection

ratio = 1.0 ($P < 0.01$). Therefore, the patterns of elk use in these higher stocked pastures was of interest. Elk selected these heavily grazed pastures disproportionately ($\chi^2 = 22$, $P < 0.01$) relative to the timing of use by livestock (Table 3). Elk demonstrated a preference for these pastures before livestock grazed then (selection ratio = 1.6, $P < 0.01$) and avoided these more heavily stocked pastures after they were grazed by livestock (selection ratio = 0.7). The elk used pastures with livestock proportional to availability (selection ratio not different from 1.0). More productive pastures are likely to be stocked heavier with livestock and elk utilized these more productive pastures before livestock are turned in. After the grazing season, elk selected for pastures with the greater forage density (Table 4). During winter, elk selected preferentially selected pastures with >0.3 forage density (selection ratio >1.0, $P < 0.01$) and avoided pastures with forage density ≤0.3 (selection ratio <1.0, $P < 0.01$). Previous research showed that the selection ratio of feeding elk was correlated with biomass of the vegetation structural stages (Rumble et al. 2007) probably because they can forage more efficiently during winter where there is greater biomass (Parker et al. 1984, Wickstrom et al. 1984). It appears that elk selected pastures during winter where they could forage efficiently.

Elk selected ($\chi^2 = 5.3$, $P = 0.07$)pastures slightly different from the predicted habitat suitability from ArcHSI (Table 5). Although the selection ratios appeared to be statistically different among the categories of habitat suitability, Bonferroni corrected *p*-values for selection ratios of categories indicated no selection (e.g., selection ratios did not differ from 1.0, $P > 0.15$). After applying the adjustments to forage values in ArcHSI that reflected the proportion of forage remaining after livestock use, the observed use by elk of pastures during winter deviated even less from, and did not differ from predicted patterns (e.g., smaller $\chi^2 = 2.7$, $P = .26$, Table 6).

Elk distributions during winter may not depend entirely upon the forage available. Additionally, elk movements onto winter range are determined largely by snow accumulations (Benkobi et al. 2005) and appeared to concentrate at the northern edge of the winter range forage may not have been limiting their distributions. Cattle use of Black Hills National Forest Lands is highly biased toward bottomlands or meadows (Hamm 1973) as was the distribution of foraging elk (Rumble et al. 2007). Many of these large meadows have improved roads in them which when modeled in the ArcHSI reduce the habitat suitability by 50% out to a distance of 260-300m. This reduction in habitat suitability would be reflected in the summaries for pastures, but elk could perhaps use these meadows at night and retreat into the forest away from roads during the day (e.g., Millspaugh 1999).

While we believe the modeling approach taken for estimating the effects of livestock grazing on elk has validity, the uncertainty resulting from our tests, (above) leads us to not recommend broad application of this grazing module until further testing has been completed. We are encouraged that there was strong selection by elk for pastures with greater forage density. Our approach to modeling the effects of livestock on elk applies forage and cover values to vegetation structural stages and in calculating an area weighted habitat suitability index defaults to a forage density estimate of forage value. Assuming that the effects of grazing incorporated into the model accurately reflect habitat suitability for elk, a partial list of factors which could influence our tests follows. 1) Although efforts were made during elk capture on summer ranges to ensure a random sample, the distribution on winter range was clustered to some degree. 2) There were not enough radio marked elk or locations during the winter 1999-2000 to provide an unbiased estimate of elk use relative to habitat suitability in pastures. This was evident in analyses of habitat suitability in vegetation structural stage polygons within pastures—some structural stages rated to be good

habitat suitability did not have any elk locations; others rated lower habitat suitability had. We can not be certain any unused habitats did not have other elk present. 3) Habitat selection by elk may not be entirely a function of habitat suitability. Social interactions among herds without radiomarked individuals may preempt use by other herds. As elk concentrate on winter range at higher densities, the predictions of an ideal free distribution reduce the likelihood of are that use of better habitats becomes full and elk would be force to make greater use of lower quality habitats (but they still should avoid the poorest habitats as seen in our model tests). 4) the limited size of our study area determined from fixed kernel utilization distribution can result in use and availability distributions that do not differ at larger scales (Kernohan et al. 1998). 5) southerly elk movements to, and distribution on winter range are determined largely by snow depth at higher altitudes immediately north of the winter range for this elk population (Benkobi et al. 2005). During winter some, but not all, of the roads on the are used by snowmobile use and thus, could alter the distribution of elk on a portion of the winter range. 6) Season of use by livestock is known to be important in the vegetative response to grazing. If grazing ceases prior to appearance of grass reproductive structures and is followed by a period with adequate rainfall, considerable regrowth can occur (Mueggler, 1967). These conditions can be beneficial elk (Skovlin et al, 1983), but are not predictable. Therefore we did not attempt to incorporate regrowth into our model.

GRAZING MODULE FOR ARCHSI

Currently, ArcHSI calculates habitat suitability index (HSI) for elk on the basis of four parameters: 1) forage value (FV), 2) cover value (CV), 3) habitat distribution value (HDV) and 4) proximity to roads. The grazing module is for winter elk habitat only. The inclusion of a grazing

module included multiplying FV for vegetation structural stages times the proportion of residual standing crop and using this value as FV in calculation of habitat suitability.

Information about the grazing season must be incorporated into an ArcInfo polygon coverage of pastures with annual operating plan information. The coverage must include the following data items: pasture identification (PAST_ID, numeric), the number of cow-calf pairs permitted (COW_CALF, numeric), the on-date for livestock (ON_DATE, date), and the off-date for livestock (OFF_DATE, date). Pasture, as used here includes vegetation structural stages within a fenced area and will include meadows and timbered lands. The polygon coverage of vegetation structural stages must correspond to pastures boundaries. This requires intersecting the pasture boundaries with the vegetation coverage before applying ArcHSI to a vegetation coverage. Other requirements for the ArcHSI model (see Juntti and Rumble 2006) are applicable. To execute the grazing module for ArcHSI, choose elk as the species from the menu and winter as the season. The user will be prompted to identify the GIS coverage with annual operating plan information. If a valid coverage exists, grazing effects are calculated; otherwise, grazing effects are omitted.

Figure 2 depicts habitat suitability for an area before and after incorporating grazing information. The effects of roads are evident in this model output; HSI categories are lower when grazing is considered reflecting the forage removed by livestock. Although we did not include road effects in our tests, roads clearly have effects on elk habitat suitability (Lyon 1979, Lyon 1983, Rowland et al. 2000, Wisdom et al 2004). Nonetheless, at high road densities, elk cannot avoid some primitive roads (Rumble et al. 2005).

Figure 1. Study area in west –central and northern Black Hills, South Dakota.

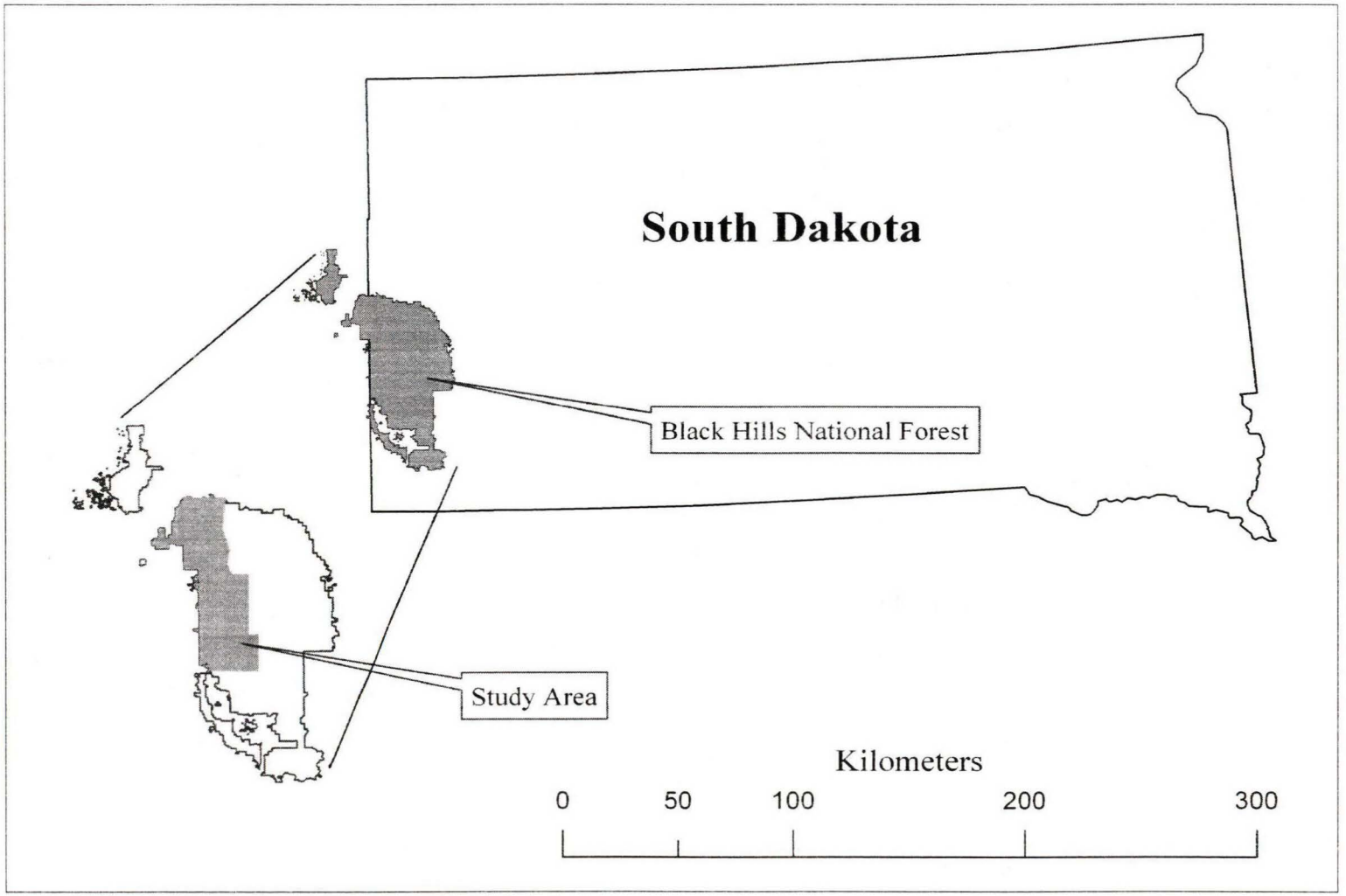

Figure 2. ArcHSI model output for elk A) without correcting forage value of vegetation structural stages for forage removed by livestock and B) with corrections to forage value of vegetation structural stages for forage removed by livestock

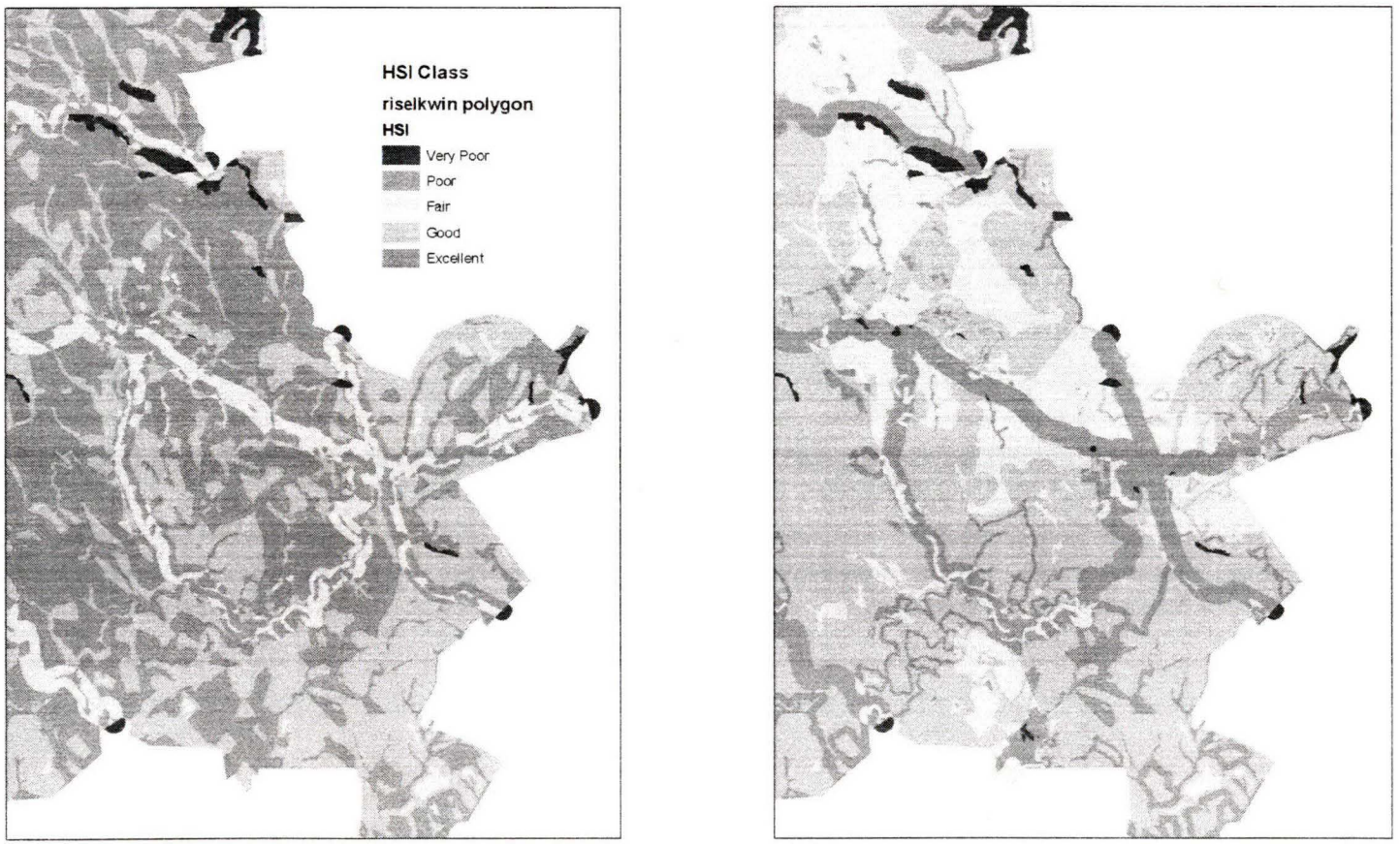

Table 1. Standing crop (oven dry weight) of vegetation cover types and structural stages on the Black Hills National Forest, South Dakota.

Cover type	Structural Stage	Standing crop (kg/ha)
Grasslands		1429
Ponderosa pine	Grass/forb	707
	Shrub/seedling	636
	Sapling/pole 0-40% OCC	434
	Sapling/pole 41-7-0% OCC	284
	Sapling/pole >70% OCC	154
	Mature/sawtimber 0-40% OCC	523
	Mature/sawtimber 41-70% OCC	434
	Mature/sawtimber >70% OCC	193
Quaking aspen	Shrub/seedling	708
	Sapling/pole 0-40% OCC	718
	Sapling/pole 41-7-0% OCC	600
	Sapling/pole >70% OCC	556
	Mature/sawtimber 0-40% OCC	715
	Mature/sawtimber 41-70% OCC	661
	Mature/sawtimber >70% OCC	593
White spruce	Grass/forb	1166
	Seedling/shrub	656
	>2.54 cm dbh 0-40% OCC	318
	>2.54 cm dbh 41-70% OCC	183

Table 1. Continued.

	>2.54 cm dbh >70% OCC	197
Mountain mahogany shrublands		125

[1] Sapling/pole = 2.54 – 25.4 cm dbh, mature/sawtimber = >25.4 cm dbh. OCC = overstory canopy cover. Structural stage categories for trees were modified slightly from Buttery and Gillam (1983). See Rumble et al (2007) for explanation of vegetation and structural stage categories.

Table 2. Observed and expected elk locations from during summer relative to stocking rates of livestock in pastures between June and October 1999[1,2].

Stocking rate for livestock [3]	Proportion of study area	Expected elk use	Observed elk use	Selection ratio	Bonferroni corrected *p*-value $H_o = 1.0$[4]
Low	0.71	400	345	0.86	<0.01
Moderate	0.21	117	143	1.22	0.35
High	0.08	45	74	1.66	<0.01

[1] Because of Jasper fire in late August 2000 this analysis only included data from 1999 grazing season.

[2] $\chi^2 = 29.2, P < 0.01$

[3] Low <3.03 cow-calf pair days/acre, moderate 3.03 to <4.8 cow-calf pair days/acre, and high .4.8 cow-calf pair days/acre. Category intervals were determined in ArcView using a Jenk's optimization (ESRI 1996).

[4] Probability that selection ratio equal 1.0 or no evidence of selection.

Table 3. Observed and expected use by elk of pastures stocked at >11.9 cow-calf pair days/ha before, during and after cattle grazing from 1 June to 31 October of 1999-2001.[1,2]

Category	Proportion of study area	Expected use by elk	Observed use by elk	Selection ratio	Bonferroni corrected *p*-value $H_o = 1.0$[3]
Before	0.33	42	67	1.61	<0.01
During	0.26	34	26	0.77	0.35
After	0.42	53	35	0.67	<0.01

[1] To ensure adequate sample, necessitated selecting all pasture stocked at ≥ 11.9 cow-calf pair days/ha for the entire study area.

[2] $\chi^2 = 21.6, P < 0.01$.

[3] Probability that selection ratio equal 1.0 or no evidence of selection.

Table 4. Observed and expected elk use of pastures during winter relative to forage density after grazing by livestock.

Forage density[2]	Proportion of study area available	Expected use by elk	Observed use by elk	Selection ratio	Bonferroni corrected *p*-value $H_o = 1.0$[3]
>0.40 – 0.45	0.09	24	42	1.72	<0.01
>0.30 – 0.40	0.35	90	115	1.23	<0.01
0.2 – 0.30	0.55	142	99	0.70	<0.01

[1] $\chi^2 = 30.9, P < 0.01$

[2] $Forage\ density = \frac{\sum_i Standing\ crop_i \times area_i \times proportion\ residual_i}{1429\ kg/ha \times Pasture\ area}$, a pasture was ungrazed and comprise entirely of grassland would have a forage density of 1.0.

[3] Probability that selection ratio equal 1.0 or no evidence of selection.

Table 5. Observed and predicted elk use of pastures summarized to HSI categories during winter modeled by ArcHSI.[1]

HSI category[2]	Proportion of study area available	Expected use by elk	Observed use by elk	Selection ratio	Bonferroni corrected *p*-value $H_o = 1.0$[3]
0.35-<0.45	0.04	10	6	0.58	0.52
0.45-<0.65	0.66	169	159	0.94	0.53
0.65 – 1.0	0.30	77	91	1.19	0.14

[1] $\chi^2 = 5.3$, $P = 0.07$

[2] Category ranges selected to ensure expected counts >5 in each cell and follow categories from Rumble et al. (2007).

[3] Probability that selection ratio equal 1.0 or no evidence of selection.

Table 6. Observed and predicted elk use of pastures summarized to HSI categories modeled by ArcHSI after adjusting forage values in the model for the amount of forage remaining after livestock.[1]

HSI category[2]	Proportion of study area	Expected use by elk	Observed use by elk	Selection ratio	Bonferroni corrected *p*-value $H_o = 1.0$[3]
0.00 - <0.40	0.07	18	14	0.76	0.88
40 – 0.60	0.82	209	219	1.05	0.34
>0.60 – 1.0	0.11	29	23	0.81	0.84

[1] $\chi^2 = 2.68$, $P = 0.26$

[2] Category ranges selected to ensure expected counts >5 in each cell and follow categories from Rumble et al. (2007).

[3] Probability that selection ratio equal 1.0 or no evidence of selection.

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